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# THE POSSIBLE USE OF THE CLOSED CIRCUIT TELEVISION SYSTEM FOR OPTICAL RANGEFINDING



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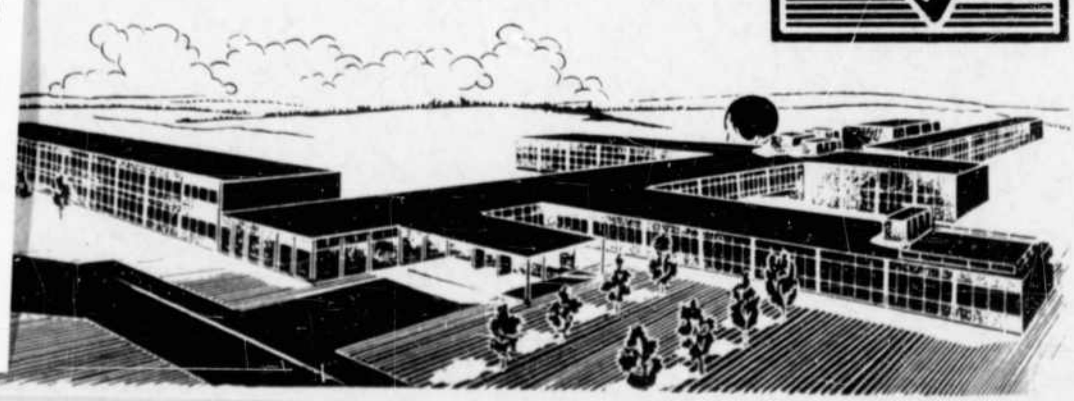

## NOTICES

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Project 7072
Task 70827

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WRIGHT-PATTERSON AIR FORCE BASE, OHIO

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## FOREWORD

This technical report was accomplished under Project 7072 "Research on the Quantum Nature of Light", Task 70827, "Light Amplification", with Mr. Gebel as task scientist.

The author wishes to express his sincere gratitude to Dr. Lee Devol, Laboratory Chief, Solid State Physics Research Laboratory and Major William Lauterbach for technical review of this report, and to acknowledge valuable assistance in its preparation by Mr. Roy Hayslett.

This report was not published at an earlier date because of previous classification.

## ABSTRACT

A new transducer capable of automatic background compensation is suggested for use in an electronic comparator system employed as a passive optical rangefinding technique. The transducer, which is a vacuum tube similar to the image orthicon, achieves the background compensation by neutralization of opposite charge patterns on a special target plate structure. Some of the theoretical capabilities and sensitivities of such a system are analyzed.

## INTRODUCTION

For a better understanding of the principles involved in automatic electronic range finding, it is suggested that ARL TR 60-302, "Automatic Optical Rangefinder", by Werner Rambauske and Hubert Kuesters, and ARL TN 60-109, "A Super Fast Recorder for Day and Night Observations of Space Vehicles Using a Light Amplifier Capable of Suppressing the Background and Discriminating Moving Objects", by Radames K.H. Gebel, be read first.

To achieve a satisfactory automatic optical range finder, Dr. Lee Devol, Chief, Solid State Physics Research Laboratory, suggested the combining of the principles used in the sequential light amplifier system and in the High Speed Optical Comparator described in ARL TR 60-302.

## THE TECHNICAL ARRANGEMENT

The background compensating transducer conceived by the author and described in ARL TN 60-109 can be used in an arrangement as shown by Figure 1, for optical range finding.

The photocathode of the transducer tube in this figure is alternately exposed to the light from each of two lens systems, by means of a mirror which locks during the selected scanning field times into positions 1 or 2. For high speed operation, two Kerr Cell shutter arrangements or two pulsed image converter tubes may be used if the latter can be sufficiently well matched to each other. The rotatable mirror is then replaced by a proper optical arrangement which alternately focuses the images onto the same photocathode area.

In position 1 the stream of electrons procuded by the photocathode, corresponding to the optical image focused onto it, is sufficiently accelerated to produce a "secondary emission yield" greater than 1 on the target plate, resulting in a positively charged pattern. With the mirror switched to position 2, the accelerating voltage is reduced, or a decelerating screen is operated so that the secondary

emission yield effective on the target plate is less than 1, depositing a negatively charged pattern. Thus electrons are now supplied to the target plate which neutralize the positive charge previously obtained. The image section of this transducer obviously has to be designed in such a manner that the charge patterns have the same dimensions in positions 1 and 2; when this is done, effective neutralization of the two charge patterns can be accomplished by choosing the proper settings of apertures 1 and 2. If, by proper optical aligning of the two lenses, identical charge patterns are obtained for a background at essentially an infinite distance, which may be formed by clouds, stars, etc., then an object in the foreground will not be completely compensated and a voltage pattern on the target plate will result from which the range to the object can be obtained. During the time intervals the mirror is changing positions, no voltage is supplied to the photocathode. The target plate is scanned only when turning from position 2 to 1, at which time the information is given to the storage reproducer or the computer.

## THE RESOLUTION AND ACCURACY

It is assumed that any image disparity between either the size or the position of the positive and negative image charges on the target plate produced by optical or geometrical inaccuracies is sufficiently smaller than the width of one line of resolution, so that it may be neglected.

The smallest resolvable angle $\alpha_{res.}$ in radians (Figure 2) corresponding to one line of resolution when focusing for infinity is

$$\alpha_{res.} = \frac{\ell_{res.}}{f} = \frac{S}{Rf} \qquad (1)$$

where $\ell_{res.}$ = width of one line of resolution in mm at the transducer photocathode

$S$ = effective length in mm of the transducer photocathode

$R$ = number of effective television resolution lines of transducer photocathode

$f$ = focal length in mm of optical system

$n$

If $\alpha_{res.}$ is given, then the number of resolution lines which the object will cover on the reproducer screen is

$$n = \frac{\ell}{d\,\alpha_{res.}} \tag{2}$$

where $d$ is the distance of the object from the optical system and $\ell$ is its apparent dimension. However, even though an object may have a size corresponding to less than one resolution element it will be reproduced as large as one resolution element, if its contrast and brightness are sufficient for detection.

The limiting accuracy of such systems can be calculated using the following reasoning: The system is assumed to be aligned so that the length and position of line c of Figure 2 is the same for the two optical systems at A and C. Movement of the object from B' to $B_1$ along d' can be observed by lens system 1 only if the distance $p_1$ is of sufficient length to correspond to one line of resolution on the sensor. The shortest distance between point $B_m$ and line d, which corresponds to m lines of resolution, we shall call $p_m$. Then

$$\tan.\beta = \frac{1/2\,b}{d'} \tag{3}$$

$$\beta_m = \beta + m\,\alpha_{res.} \tag{4}$$

$$d'_o = \frac{0.5\,b}{\tan.\beta_m} \tag{5}$$

Hence

$$d'_m = d' - \frac{0.5\,b}{\tan(\beta + m\alpha_{res.})} \tag{6}$$

THE SENSITIVITY

The limiting sensitivity achieveable by such a system is basically determined by the degree of compensation of the luminous background at the target plate and by the fundamental statistical fluctuations in the charge pattern of the transducer

target plate.

If perfect compensation of the background is assumed, the statistical fluctuations in the background will still remain and add geometrically. The limiting sensitivity for any situation in detecting light as determined by statistical considerations has been treated extensively by the author in his paper: "The Limitations in Resolution and Discrimination in Brightness Differences for Light Amplifier Systems Using Contrast Enhancement", in the Ohio Journal of Science, Vol. 61, No. 6, November 1961, pages 332-340, which may be used for analyzing the above situation.

Example: A range finder system as shown by Figure 1 with a 4 meter base and an optical system with 500 mm focal length is used. The effective photocathode size is 25 mm and 1000 TV lines of resolution are possible. Effective horizontal object size = 2 meters. The smallest resolvable angle is, using Eq (1)

$$\alpha_{res.} = \frac{25}{1000 \times 500} = 5 \times 10^{-5} \text{ radians} \approx 10 \text{ sec. of arc.}$$

The number of horizontal resolution lines by which the object is resolved if at a distance of 10 Km, using Eq (2) is

$$n = \frac{2}{10\,000 \times 5 \times 10^{-5}} = 4$$

Assuming the background alignment of the system was made for 10 Km, then the distance which the object has to move toward the rangefinder so that $p_m$ corresponds to one resolution element, using Eq (4), is

$$d'_m = 10\,000 - \frac{0.5 \times 4}{20 \times 10^{-5} + 1 \times 5 \times 10^{-5}} = 2000 \text{ meter}$$

Actually an equivalent separation of one resolution line will probably not be adequate for positive detection; if we assume that a separation of 6 lines is adequate, $d_m$ is as follows

$$d'_m = 10\,000 - \frac{0.5 \times 4}{20 \times 10^{-5} + 6 \times 5 \times 10^{-5}} \approx 6000 \text{ meter}$$

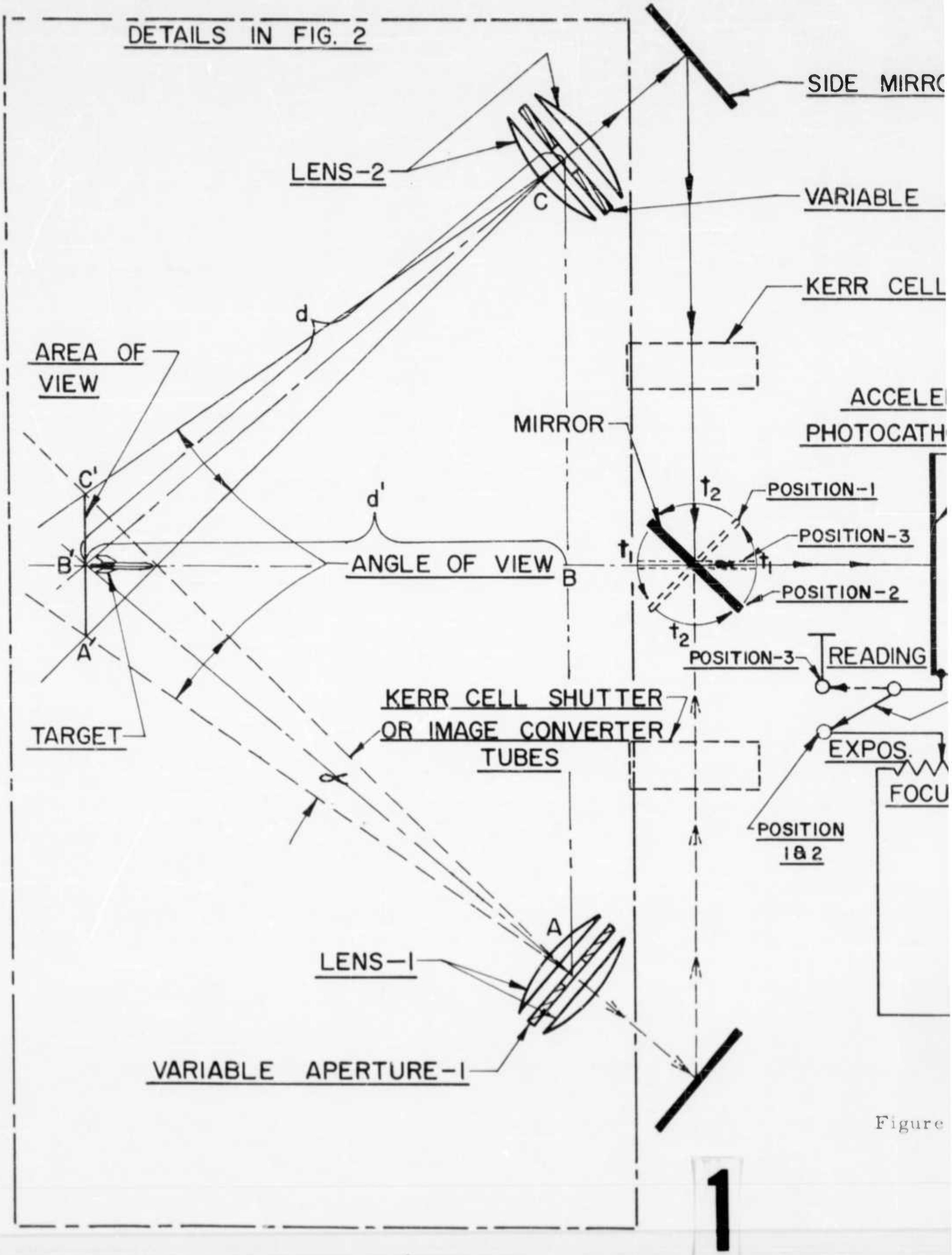
(where $\tan\beta = \beta$ in radians is used, since $\sphericalangle \beta < 5^\circ$ ).

## REFERENCES

Gebel, Radames K.H. "A Super Fast Recorder for Day and Night Observations of Space Vehicles Using a Light Amplifier Capable of Suppressing the Background and Discriminating Moving Objects."

Gebel, Radames K.H. "The Limitations in Resolution and Discrimination in Brightness Differences for Light Amplifier Systems, Using Contrast Enhancement."

Rambauske, W. and Kuesters, H. "Automatic Optical Rangefinder."


DETAILS IN FIG. 2
SIDE MIRR
LENS-2
C
VARIABLE
KERR CELL
d
AREA OF VIEW
ACCELE
MIRROR
PHOTOCATH
C'
d'
$t_2$
POSITION-1
POSITION-3
$t_1$
$t_1$
B'
ANGLE OF VIEW
B
POSITION-2
A'
$t_2$
POSITION-3
READING
KERR CELL SHUTTER OR IMAGE CONVERTER TUBES
TARGET
EXPOS.
FOCU
$\alpha$
POSITION 1&2
A
LENS-1
VARIABLE APERTURE-1

Figure

1

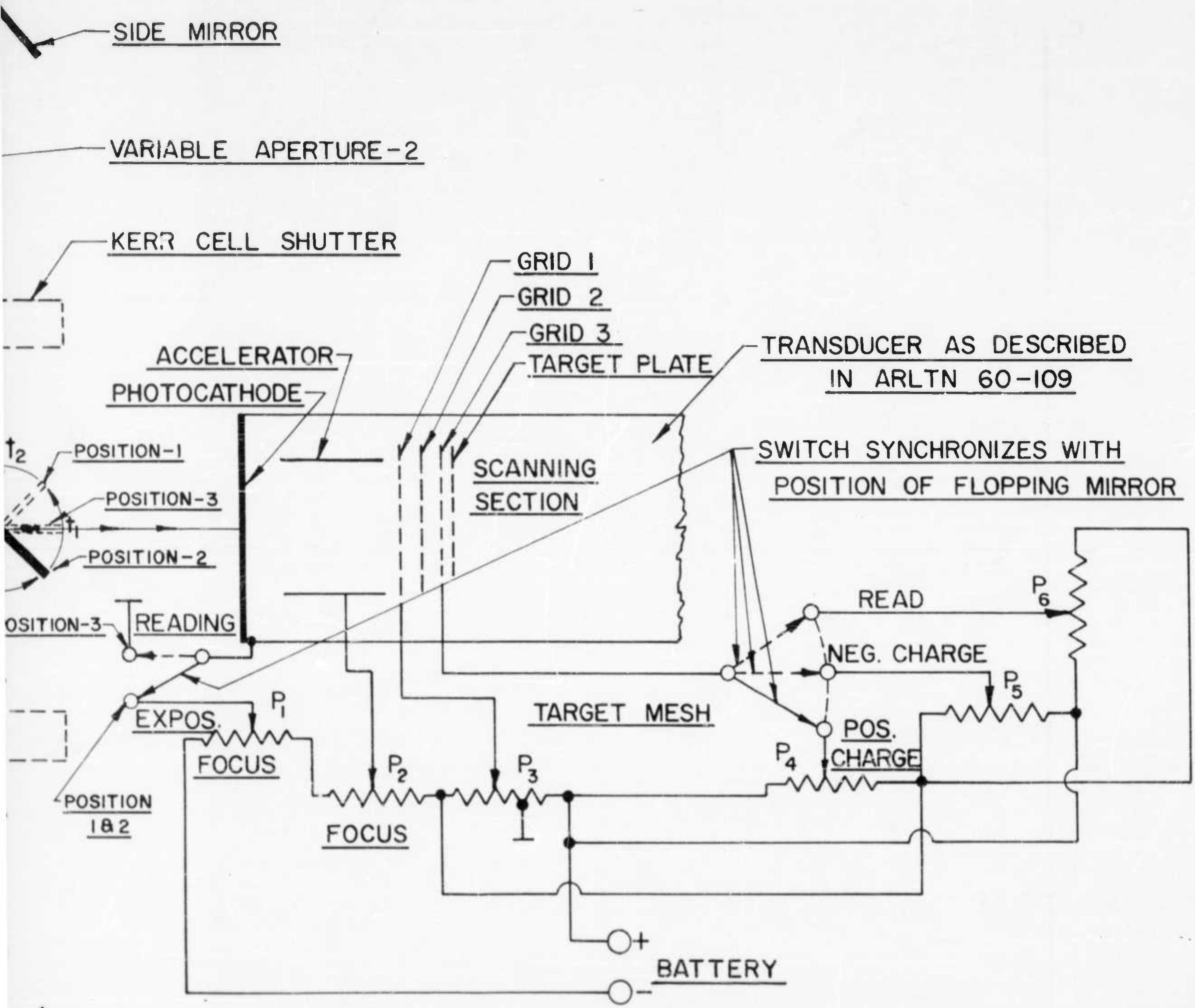



Figure 1. High Speed Optical Comparator With Automatic Background Compensation

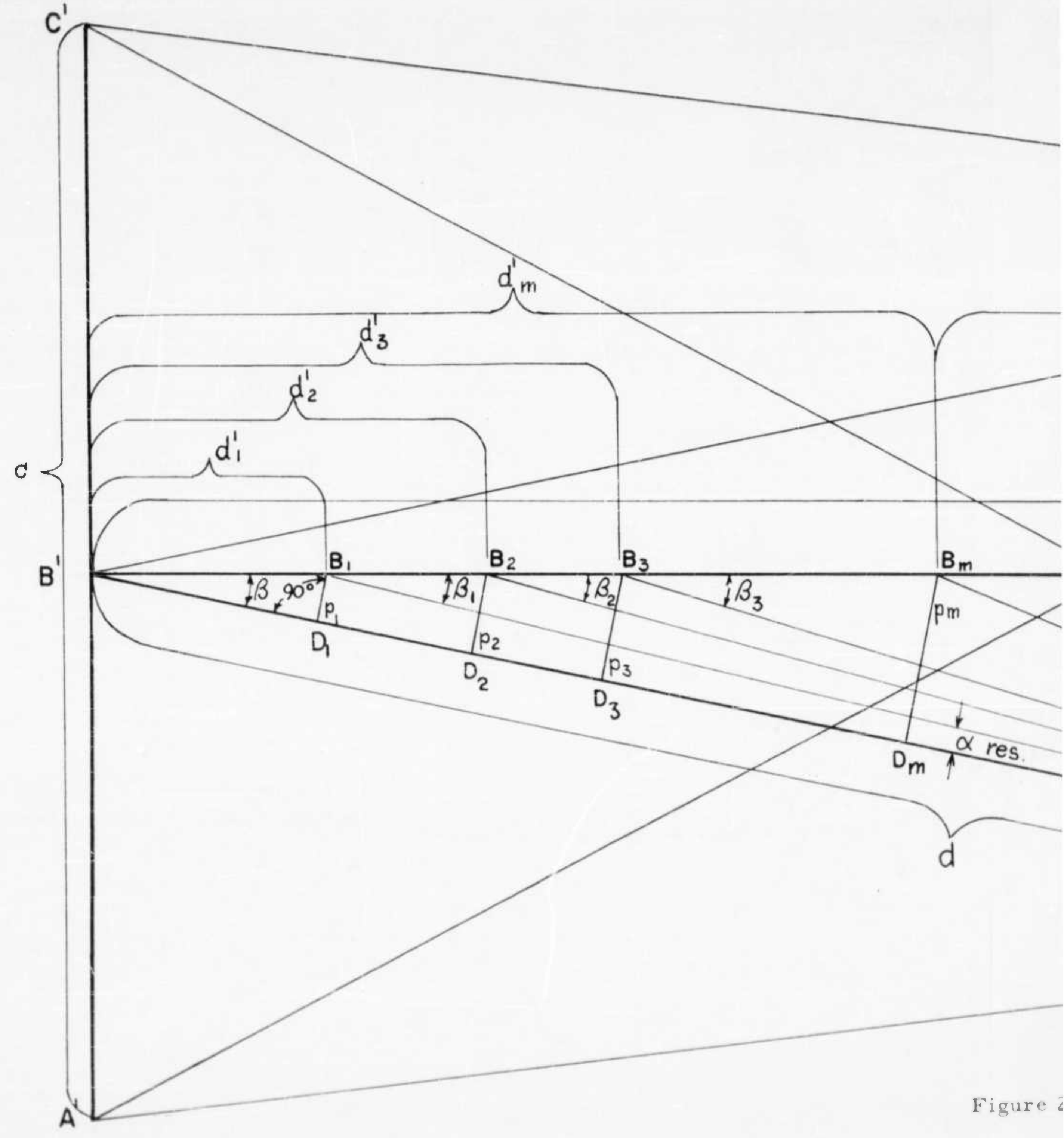

C'
c
B'
A'
d'm
d'3
d'2
d'1
B1
B2
B3
Bm
β
90°
β1
β2
β3
p1
p2
p3
pm
D1
D2
D3
Dm
α res.
d

Figure 2

1

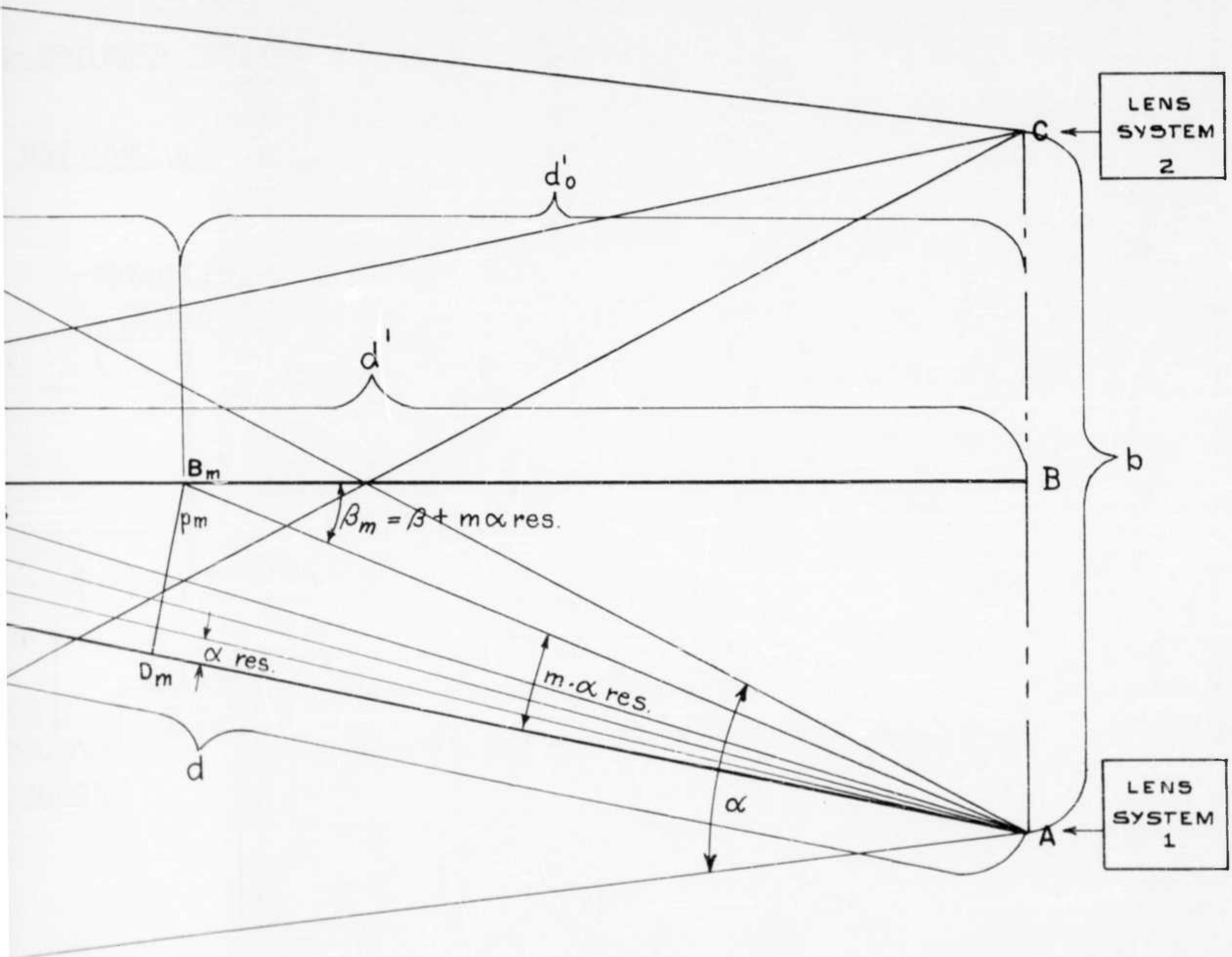



Figure 2. Diagram for Accuracy Determination

Aeronautical Research Laboratories, Wright-Patterson AFB, Ohio. THE POSSBLE USE OF THE CLOSED CIRCUIT TLEVISION SYSTEM FOR OPTICAL RANGE FINDING by R. K. H. Gebel. Solid State Physics Lab, ARL. July 1962. 5 p. incl. illus. (Project 7072, Task 70827) (ARL 62-383) Unclassified Report

A new transducer capable of automatic background compensation is suggested for use in an electronic comparator system employed as a passive optical rangefinding technique. The transducer, which is a

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vacuum tube similar to the image orthicon, achieves the background compensation by neutralization of opposite charge patterns on a special target plate structure. Some of the theoretical capabilities and sensitivities of such a system are analyzed.

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